# SECTION I—AEROLOGY.

## SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Sept. 1, 1916.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEWS for January, April, and May, 1916, 44 : 2, 179, 180, and 244.

The monthly means and departures from normal values given in Table 1 show that direct solar radiation intensities averaged below normal at all stations except Santa Fe, N. Mex., the minus departures being especially pronounced at Madison, Wis. The intensities were unusually low at this station on July 27, 28, and 29, at Lincoln, Nebr., on July 27 and 29, and at Washington, D. C., on July 29, during the prevalence of marked hazy or smoky conditions. Haze or smoke was quite generally recorded during the latter part of July at stations in the northeastern part of the United States, following a period of hot dry weather in the north-Central States—weather conditions that favored intense vertical convection and the introduction of great quantities of dust into the atmosphere. At the same time forest fires were reported in Michigan and in Ontario, Canada. At Washington and Lincoln during this period it was observed that the sun was very red at sunrise, and on the 30th at Washington the sky was so red after sunset that the city fire department was kept busy responding to inquiries as to the location of a supposed conflagration. At Madison the haze was so thick as to cut off sky colors.

Skylight polarization measurements made at Washington on six days give a mean of 54 per cent, with a maximum of 64 per cent on July 5. This latter measurement is above the average July maximum for Washington.

TABLE 1.—*Solar radiation intensities during July, 1916.*

[Gram-calories per minute per square centimeter of normal surface.]

**Washington, D. C.**

| Date. | Sun's zenith distance. 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air mass. 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* |
| A. M. | | | | | | | | | | |
| July 5 | ..... | 1.31 | ..... | ..... | 1.21 | ..... | ..... | 1.11 | ..... | ..... |
| 6 | ..... | 1.25 | 1.15 | 1.07 | 0.99 | 0.92 | 0.85 | ..... | ..... | ..... |
| 7 | ..... | 1.22 | 1.08 | 0.99 | 0.89 | ..... | ..... | ..... | ..... | ..... |
| 12 | ..... | 0.98 | 0.83 | 0.70 | ..... | ..... | ..... | ..... | ..... | ..... |
| 13 | 1.22 | 1.10 | 1.00 | 0.91 | 0.84 | ..... | ..... | ..... | ..... | ..... |
| 29 | 0.89 | 0.74 | 0.73 | 0.65 | 0.57 | 0.50 | 0.44 | 0.37 | ..... | ..... |
| Monthly means | 1.06 | 1.10 | 0.96 | 0.86 | 0.90 | (0.71) | (0.64) | (0.74) | ..... | ..... |
| Departure from 8-year normal | −0.19 | −0.02 | −0.03 | −0.05 | +0.01 | −0.06 | −0.01 | +0.07 | ..... | ..... |
| P. M. | | | | | | | | | | |
| July 6 | ..... | ..... | ..... | ..... | 0.89 | 0.79 | 0.73 | ..... | ..... | ..... |
| 12 | ..... | 1.09 | ..... | 0.91 | 0.81 | ..... | ..... | ..... | ..... | ..... |
| Monthly means | ..... | (1.09) | ..... | (0.91) | (0.85) | (0.79) | (0.73) | ..... | ..... | ..... |
| Departure from 8-year normal | ..... | +0.05 | ..... | +0.05 | +0.05 | −0.05 | −0.02 | ..... | ..... | ..... |

TABLE I.—*Solar radiation intensities during July, 1916*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

**Madison, Wis.**

| Date. | Sun's zenith distance. 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air mass. 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* |
| A. M. | | | | | | | | | | |
| July 6 | 1.18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 10 | ..... | 1.14 | 1.02 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 11 | 1.24 | 1.12 | 1.01 | 0.92 | ..... | ..... | ..... | ..... | ..... | ..... |
| 18 | 1.15 | 0.97 | 0.90 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 21 | 1.29 | 1.23 | 1.15 | 1.07 | 1.00 | 0.93 | ..... | ..... | ..... | ..... |
| 22 | 1.24 | 1.19 | 1.10 | 1.03 | ..... | ..... | ..... | ..... | ..... | ..... |
| 27 | 0.97 | 0.75 | 0.65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | 1.01 | 0.82 | 0.67 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 29 | 0.79 | 0.71 | 0.64 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | 1.11 | 0.99 | 0.89 | 1.01 | (1.00) | (0.93) | ..... | ..... | ..... | ..... |
| Departure from 6-year normal | −0.10 | −0.12 | −0.12 | +0.08 | ..... | ..... | ..... | ..... | ..... | ..... |
| P. M. | | | | | | | | | | |
| July 11 | ..... | 1.05 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 21 | ..... | 1.13 | 1.05 | 0.96 | 0.90 | ..... | ..... | ..... | ..... | ..... |
| 27 | ..... | 0.79 | 0.71 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | ..... | 0.81 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | ..... | 0.95 | (0.88) | (0.96) | (0.90) | ..... | ..... | ..... | ..... | ..... |
| Departure from 6-year normal | ..... | −0.16 | −0.01 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

**Lincoln, Nebr.**

| Date. | Sun's zenith distance. 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air mass. 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* |
| A. M. | | | | | | | | | | |
| July 1 | ..... | 1.32 | 1.22 | 1.12 | 1.03 | 1.00 | 0.86 | ..... | ..... | ..... |
| 6 | 1.26 | 1.16 | 1.06 | 0.97 | 0.92 | 0.89 | 0.83 | ..... | ..... | ..... |
| 7 | 1.35 | ..... | 1.11 | 1.01 | 0.93 | 0.89 | 0.85 | ..... | ..... | ..... |
| 8 | 1.17 | 1.12 | 1.03 | ..... | 0.82 | 0.78 | 0.69 | ..... | ..... | ..... |
| 10 | 1.26 | 1.05 | 0.95 | 0.82 | 0.72 | 0.64 | ..... | ..... | ..... | ..... |
| 11 | 1.28 | 1.00 | 0.88 | 0.79 | 0.71 | 0.65 | ..... | ..... | ..... | ..... |
| 15 | 1.32 | 1.16 | 1.08 | 0.98 | 0.89 | 0.81 | ..... | ..... | ..... | ..... |
| 18 | 1.23 | 1.15 | 1.00 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 20 | 1.43 | 1.35 | 1.26 | 1.16 | 1.05 | 0.95 | 0.89 | ..... | ..... | ..... |
| 21 | 1.42 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 1.36 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 25 | ..... | 1.24 | 1.14 | 1.05 | 0.97 | 0.95 | 0.88 | ..... | ..... | ..... |
| 26 | ..... | ..... | ..... | ..... | 0.71 | ..... | ..... | ..... | ..... | ..... |
| 27 | 1.27 | ..... | ..... | ..... | 0.65 | 0.61 | ..... | ..... | ..... | ..... |
| 28 | 1.34 | 1.24 | 1.15 | 1.07 | 0.99 | 0.93 | 0.85 | ..... | ..... | ..... |
| 29 | 1.14 | 0.96 | 0.79 | 0.73 | 0.61 | 0.54 | 0.48 | ..... | ..... | ..... |
| 31 | 1.31 | 1.11 | 1.00 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | 1.30 | 1.16 | 1.05 | 0.97 | 0.85 | 0.80 | 0.79 | ..... | ..... | ..... |
| Departure from 2-year normal | −0.03 | −0.04 | −0.05 | −0.05 | −0.06 | −0.05 | −0.03 | ..... | ..... | ..... |
| P. M. | | | | | | | | | | |
| July 5 | ..... | 1.19 | 1.04 | 0.94 | 0.85 | 0.78 | 0.74 | ..... | ..... | ..... |
| 6 | ..... | 1.15 | 1.07 | 0.99 | 0.90 | 0.82 | 0.72 | ..... | ..... | ..... |
| 7 | ..... | 1.18 | 1.02 | 0.87 | 0.79 | 0.72 | 0.65 | ..... | ..... | ..... |
| 10 | ..... | ..... | 0.98 | 0.90 | 0.79 | 0.71 | 0.63 | ..... | ..... | ..... |
| 14 | ..... | 1.17 | 1.00 | 0.84 | ..... | ..... | ..... | ..... | ..... | ..... |
| 15 | ..... | 1.16 | 1.01 | 0.92 | 0.84 | 0.77 | 0.70 | ..... | ..... | ..... |
| 17 | ..... | ..... | 1.16 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 18 | ..... | 0.98 | 0.86 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 19 | ..... | ..... | 1.22 | 1.12 | 1.03 | 1.00 | 0.89 | ..... | ..... | ..... |
| 20 | ..... | 1.27 | 1.18 | 1.08 | 0.98 | 0.92 | 0.83 | ..... | ..... | ..... |
| 21 | ..... | 1.24 | 1.17 | 1.08 | 1.00 | 0.93 | 0.83 | ..... | ..... | ..... |
| 26 | ..... | ..... | ..... | 0.73 | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | ..... | 1.18 | 1.04 | 0.89 | 0.77 | 0.68 | 0.62 | ..... | ..... | ..... |
| Monthly means | ..... | 1.17 | 1.06 | 0.94 | 0.88 | 0.81 | 0.73 | ..... | ..... | ..... |
| Departure from 2-year normal | ..... | −0.01 | −0.01 | −0.03 | −0.01 | −0.01 | −0.01 | ..... | ..... | ..... |

TABLE 1.—*Solar radiation intensities during July, 1916*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Santa Fe, N. Mex.

| Date. | Sun's zenith distance. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
| | Air mass. | | | | | | | | | |
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| A. M. | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* |
| July 1 | ..... | 1.34 | 1.28 | 1.23 | 1.19 | 1.13 | 1.07 | 1.02 | ..... | ..... |
| 3 | ..... | 1.44 | 1.37 | 1.30 | 1.21 | 1.14 | 1.08 | ..... | ..... | ..... |
| 13 | 1.42 | 1.31 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 1.42 | ..... | 1.27 | 1.20 | 1.12 | 1.07 | 1.02 | ..... | ..... | ..... |
| 17 | ..... | 1.32 | 1.21 | 1.16 | 1.14 | 1.06 | ..... | ..... | ..... | ..... |
| 19 | ..... | 1.30 | 1.23 | 1.17 | 1.11 | 1.04 | 0.97 | 0.90 | ..... | ..... |
| 21 | 1.40 | 1.37 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | 1.41 | 1.35 | 1.27 | 1.21 | 1.15 | 1.09 | 1.04 | (0.96) | ..... | ..... |
| Departure from 4-year normal | −0.02 | +0.01 | +0.02 | ±0.00 | ..... | ..... | ..... | ..... | ..... | ..... |

TABLE 2.—*Vapor pressure at pyrheliometric stations on days when solar radiation intensities were measured.*

| Washington, D. C. | | | Madison, Wis. | | | Lincoln, Nebr. | | | Santa Fe, N. Mex. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates. | 8 a.m. | 8 p.m. | Dates. | 8 a.m. | 8 p.m. | Dates. | 8 a.m. | 8 p.m. | Dates. | 8 a.m. | 8 p.m. |
| 1916. | *Mm.* | *Mm.* | 1916. | *Mm.* | *Mm.* | 1916. | *Mm.* | *Mm.* | 1916. | *Mm.* | *Mm.* |
| July 5 | 10.59 | 11.38 | July 6 | 13.61 | 12.24 | July 1 | 17.37 | 17.37 | July 1 | 5.36 | 6.76 |
| 6 | 10.97 | 12.68 | 10 | 9.47 | 12.24 | 5 | 16.20 | 17.96 | 3 | 4.57 | 2.87 |
| 7 | 13.61 | 15.65 | 11 | 12.24 | 13.61 | 6 | 15.11 | 11.38 | 13 | 8.48 | 8.48 |
| 12 | 18.59 | 19.23 | 18 | 15.65 | 18.59 | 7 | 12.24 | 12.24 | 14 | 8.48 | 6.76 |
| 13 | 18.59 | 20.57 | 21 | 13.13 | 13.61 | 8 | 12.68 | 14.60 | 17 | 7.57 | 10.21 |
| 29 | 11.81 | 13.61 | 22 | 14.10 | 16.20 | 10 | 15.65 | 12.24 | 19 | 8.48 | 9.14 |
| | ..... | ..... | 27 | 16.79 | 17.37 | 11 | 16.20 | 13.61 | 21 | 8.81 | 8.56 |
| | ..... | ..... | 28 | 17.96 | 16.79 | 14 | 16.79 | 18.59 | | ..... | ..... |
| | ..... | ..... | 29 | 17.37 | 16.20 | 15 | 16.79 | 14.60 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 17 | 15.65 | 19.23 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 18 | 16.79 | 19.89 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 19 | 16.79 | 16.20 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 20 | 12.68 | 10.21 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 21 | 11.38 | 13.13 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 22 | 14.60 | 15.11 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 25 | 12.68 | 13.13 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 26 | 13.13 | 13.61 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 27 | 15.65 | 15.65 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 28 | 16.20 | 15.65 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 29 | 15.11 | 14.10 | | ..... | ..... |
| | ..... | ..... | | ..... | ..... | 31 | 18.59 | 19.23 | | ..... | ..... |

Table 3 shows a deficiency of radiation at Washington for each decade, but especially during the last decade, the deficiency for the month amounting to about 10.9 per cent of the average July radiation. At Madison there was an excess of radiation during each decade, the excess for the month amounting to 10.6 per cent of the average July total.

The Callendar recorder at Lincoln, Nebr., has been in operation only since June 30, 1915. The daily normals are therefore for a two-year period. The departures indicate an excess in the total radiation in 1916 over that measured in 1915 of about 18 per cent.

TABLE 3.—*Daily totals and departures of solar and sky radiation during July, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

| Day of month. | | Daily totals. | | | Departures from normal. | | | Excess or deficiency since first of month. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Washington. | Madison. | Lincoln. | Washington. | Madison. | Lincoln. | Washington. | Madison. | Lincoln. |
| | | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* | *Gr.-cal.* |
| July | 1 | 510 | 621 | 683 | −25 | 67 | 88 | −25 | 67 | 88 |
| | 2 | 481 | 583 | 716 | −54 | 30 | 122 | −79 | 97 | 210 |
| | 3 | 520 | 555 | 673 | −14 | 3 | 81 | −93 | 100 | 291 |
| | 4 | 561 | 673 | 411 | 27 | 122 | −180 | −66 | 222 | 111 |
| | 5 | 555 | 652 | 697 | 22 | 102 | 108 | −44 | 324 | 219 |
| | 6 | 638 | 673 | 735 | 106 | 125 | 148 | 62 | 449 | 367 |
| | 7 | 676 | 651 | 709 | 145 | 105 | 124 | 207 | 554 | 491 |
| | 8 | 580 | 523 | 658 | 50 | −20 | 75 | 257 | 534 | 566 |
| | 9 | 244 | 701 | 596 | −285 | 160 | 15 | −28 | 694 | 581 |
| | 10 | 240 | 680 | 683 | −288 | 142 | 109 | −316 | 836 | 690 |
| | 11 | 564 | 664 | 647 | 37 | 128 | 70 | −279 | 964 | 760 |
| | 12 | 656 | 365 | 453 | 130 | −168 | −122 | −149 | 796 | 638 |
| | 13 | 602 | 596 | 381 | 77 | 65 | −192 | −72 | 861 | 446 |
| | 14 | 479 | 607 | 642 | −44 | 79 | 71 | −116 | 940 | 517 |
| | 15 | 569 | 565 | 671 | 47 | 40 | 102 | −69 | 980 | 619 |
| | 16 | 505 | 407 | 422 | −15 | −116 | −144 | −84 | 864 | 475 |
| | 17 | 225 | 608 | 368 | −293 | 88 | −196 | −377 | 952 | 279 |
| | 18 | 549 | 626 | 667 | 32 | 109 | 106 | −345 | 1,061 | 385 |
| | 19 | 410 | 486 | 482 | −105 | −29 | − 76 | −450 | 1,032 | 309 |
| | 20 | 414 | 484 | 743 | −99 | −28 | 188 | −549 | 1,004 | 497 |
| | Decade departure | ..... | ..... | ..... | ..... | ..... | ..... | −233 | 168 | −193 |
| | 21 | 466 | 660 | 705 | −46 | 151 | 153 | −595 | 1,155 | 650 |
| | 22 | 328 | 661 | 607 | −182 | 154 | 58 | −777 | 1,309 | 708 |
| | 23 | 413 | 614 | 574 | −95 | 110 | 28 | −872 | 1,419 | 736 |
| | 24 | 306 | 498 | 609 | −200 | −3 | 66 | −1,072 | 1,416 | 802 |
| | 25 | 247 | 527 | 662 | −257 | 29 | 122 | −1,329 | 1,445 | 924 |
| | 26 | 358 | 554 | 627 | −145 | 59 | 90 | −1,474 | 1,504 | 1,014 |
| | 27 | 547 | 555 | 635 | 46 | 63 | 101 | −1,428 | 1,567 | 1,115 |
| | 28 | 126 | 555 | 653 | −373 | 66 | 122 | −1,801 | 1,633 | 1,237 |
| | 29 | 582 | 471 | 589 | 85 | −15 | 61 | −1,716 | 1,618 | 1,298 |
| | 30 | 540 | 531 | 570 | 45 | 48 | 45 | −1,671 | 1,666 | 1,343 |
| | 31 | 414 | 526 | 567 | −79 | 46 | 45 | −1,750 | 1,712 | 1,388 |
| | Decade departure | ..... | ..... | ..... | ..... | ..... | ..... | −1,201 | +708 | +891 |
| Excess or deficiency since first of year. | gr.-cal. | ..... | ..... | ..... | ..... | ..... | ..... | −6,487 | +1,643 | ..... |
| | per cent. | ..... | ..... | ..... | ..... | ..... | ..... | 7.9 | 2.0 | ..... |